Check List the journal of biodiversity data

LISTS OF SPECIES

Check List 11(6): 1813, 15 December 2015 doi: http://dx.doi.org/10.15560/11.6.1813
ISSN 1809-127X

Butterflies (Lepidoptera: Papilionoidea and Hesperioidea) of the Banhado dos Pachecos Wildlife Refuge, Uruguayan Savanna Ecoregion, Rio Grande do Sul state, Brazil

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Abstract: The Pampa is a biome shared by Argentina, Brazil, and Uruguay. Despite its high biodiversity, little is known about the invertebrate fauna. The few inventories done so far were conducted outside protected areas, which could result in underestimated real biodiversity. Thus, species inventories from protected areas should be done to serve as reference for conservation. Here we survey the butterflies occurring in the Banhado dos Pachecos Wildlife Refuge, Uruguayan Savanna, Brazil. Sampling was performed between April 2012 and March 2013. After 288 hours of sampling, 1,508 individuals from 113 species were sampled; five new species records for Rio Grande do Sul state and 12 for the Uruguayan Savanna were found. Richness among families was compared to other inventories and butterfly conservation discussed concerning the conversion of grasslands into croplands/pastures. The evidence presented supports that the Pampa is a fragile environment under the pressure of habitat conversion. Biodiversity studies in fragmented areas are needed to provide essential information for conservation programs.

Key words: conservation; fragmentation; grasslands; Pampa Biome; species richness

INTRODUCTION

The Pampa Biome is an ancient complex of five ecoregions shared by Argentina, Brazil and Uruguay, which covers 1,113,752 km^2 (Bilenca and Miñarro 2004; Olson et al. 2004). The natural landscapes of the Pampa are characterized by the predominance of native grasslands intermingled with riparian forests, slope forests, ironwood forests, scrublands, palm forests, wetlands, and rocky outcrops (IBGE 2004; Boldrini 2009; Boldrini et al. 2010). As an old collection of ecosystems, the Pampa presents high biodiversity and is home to very characteristic flora and fauna. Estimates indicate the presence of approximately 3,000 plant species, over 100 mammal species, and almost 500 bird species (MMA 2007).

Despite its high biodiversity, little is known about invertebrate diversity in the Pampa. Considering that only recent studies focus on non-pest insects, some efforts made to evaluate the diversity of Coleoptera (Da Silva et al. 2013), Diptera (Hochmüller et al. 2010), Hemiptera (Mendonça Jr. et al. 2009; Bunde et al. 2010), Hymenoptera (Rosado et al. 2012), Orthoptera (Cigliano et al. 2000; Wysiecki et al. 2000), and Lepidoptera (Krüger and Silva 2003; Marchiori and Romanowski, 2006a, 2006b; Paz et al. 2008; Sackis and Morais 2008; Morais et al. 2012; Paz et al. 2013; Marchiori et al. 2014) can be highlighted. Among insect, the butterflies are considered an adequate group for studies evaluating fragmented habitats (see discussion in Bonebrake et al. 2010). Butterflies are useful as indicator species, since they play many essential roles in ecosystems and are visually appealing organisms (Fleishman and Murphy 2009). Hence, studies on butterflies can offer prospective insights into biodiversity patterns, ecological systems and conservation issues (Brown Jr., 1997; Oostermeijer and Swaay 1998; Lomov et al. 2006).

To support actions in conservation and management in areas under environmental degradation, it is important to consider the connectivity between habitat patches and estimate the biodiversity in affected regions (Fahrig 2003; Littlewood et al. 2011). Regarding the Pampa fragmentation, recent studies indicated that more than 70% of its original cover has been converted to cropland and pasture in the past few decades (Eva et al. 2003). Many ecoregions have been severely impacted by human activities, especially the Uruguayan Savanna

ecoregion where the native areas have been converted into large-scale monocultures of rice, soybean, pine and eucalyptus, and extensive pastures with exotic species for cattle and sheep rearing (IBGE 2007; Pillar et al. 2009). Nowadays, it is estimated that only 36% of the native Brazilian Uruguayan Savanna is left (CSR/IBAMA 2011), and our present field experience points out that this may well be an overestimation. The most worrying aspect is that biodiversity studies have only begun to reveal the diversity of arthropods in the Pampa and their response in the light of environment variation (Mendonça Jr et al 2015). Still, only 0.46% of the biome is guarded from threats as conservation units (areas of integral protection) (Overbeck et al. 2007). Biodiversity inventories can provide information on genetic, ecological, and taxonomic diversity, allowing areas with different levels of degradation to be compared (Motta 2002). Inventories provide a first screening of environmental health, and are essential to understand biodiversity and distribution patterns of species through landscapes (Lewinsohn et al. 2005).

Although some butterfly inventories have been published on the Pampa Biome, only two were conducted inside a protected area (Marchiori and Romanowski 2006a, 2006b). Since protected areas generally embrace more developed environments, with more diversity of resource for Lepidoptera, it is expected that they shelter more butterfly diversity when compared to the surrounding unprotected landscape. Therefore, species lists from protected areas may provide very useful information for butterfly conservation, standing as a diversity standard for management and restoration programs. The main objective of the present study is to produce a species list of the butterflies occurring in the Banhado dos Pachecos Wildlife Refuge (BPWR), in the Uruguayan Savanna ecoregion, Southern Brazil.

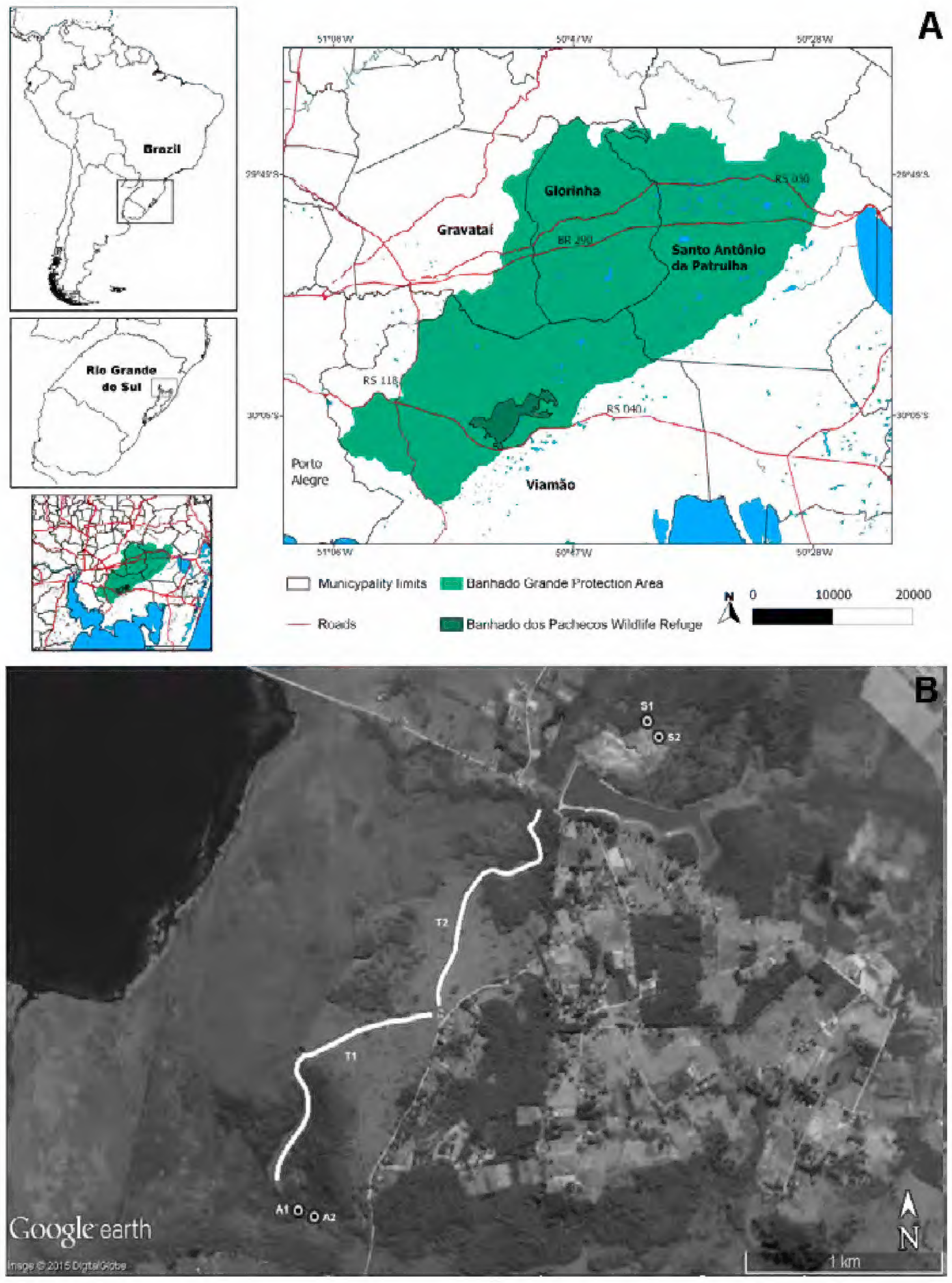

Figure 1. A: Location of Banhado dos Pachecos Wildlife Refuge (BPWR), Banhado Grande Permanent Protection Area, Rio Grande do Sul State, Brazil (modified from SEMA 2010). **B:** Satellite image showing the study sites into BPWR (modified from Google Earth). T1 and T2 - transects used for entomological netting sampling; A1 and A2 - observation by scanning areas with intermediate stage of regeneration; S1 and S2 - observation by scanning areas with early stage of regeneration. Datum: WGS84.

MATERIAL AND METHODS

Study area

The BPWR is a protected area belonging to the Department of Forests and Protected Areas of the Secretariat of Environment of Rio Grande do Sul state (DUC-SEMA). It has an area of 2,543.47 ha, located in the Águas Claras County, municipality of Viamão (Figure 1). It is part of the Banhado Grande Protection Area, consisting of extensive wetlands mixed with other formations (Accordi and Barcellos 2006). The landscape mosaic includes Restinga forests, swamp forests, slope forests, mixed grassland, and dune vegetation (Figure 2). The surrounding environmental matrix is composed of irrigated rice croplands, small farming areas, cattle pastures, eucalyptus monocultures, and suburban areas. The BPWR is located in the transition between the Central Depression and the Coastal Plain of Rio Grande do Sul state (SEMA 2010). It is part of the geomorphological unit known as "Coxilha das Lombas", an 81 km sandy region extending from the Itapuã Peninsula, located at the north end of Patos Lagoon, and heading northeast to the Barros Lagoon. It consists of small grassy hills, which originate from a Lagoon-Barrier System that emerged during the Cenozoic (Villwock and Tomazelli 2007).

The climate of the region is subtropical mesothermal humid (Köppen Cfa; Peel et al. 2007). The average annual temperature ranges from 16 to 26°C, with the average during the hottest month around 28°C and the average during the coldest month around 12°C. The annual rainfall varies between 1,000 mm and 1,500 mm, with eventual periods of prolonged water deficit between January and March (Villwock and Tomazelli 2007).

Data collection

Two different methods for sampling the butterfly fauna of the BPWR were applied, aiming to optimize the detection of species, considering both landscape heterogeneity and habitats with different conservation levels: transect entomological netting (modified from

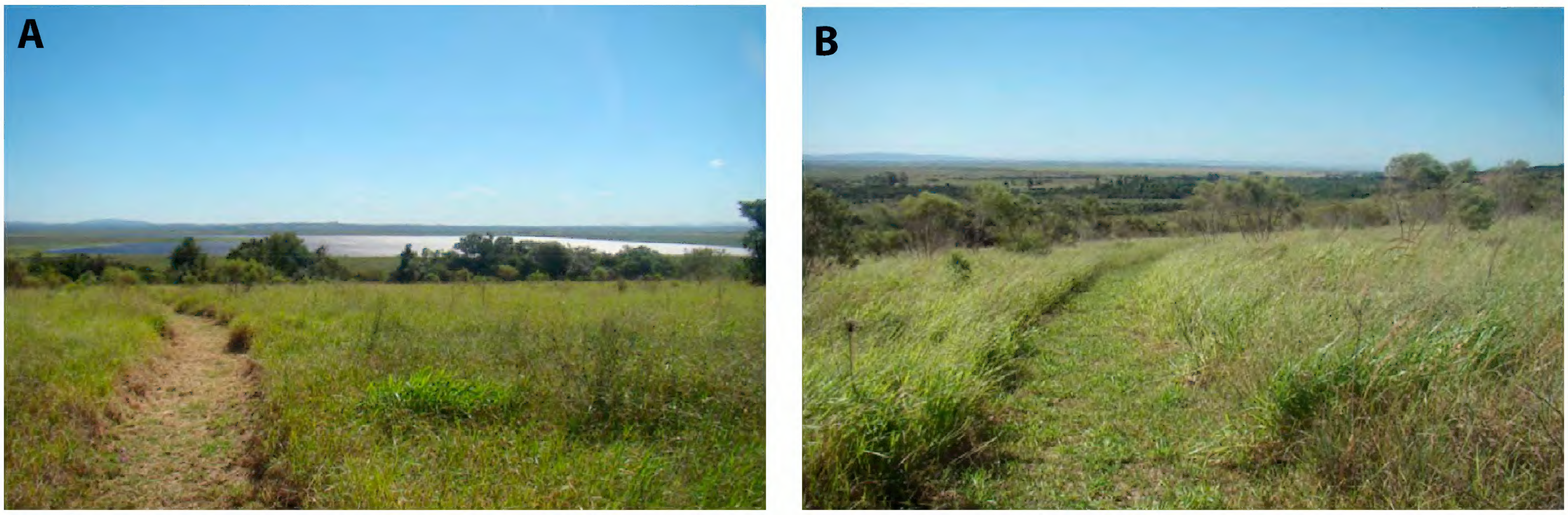

Figure 2. General view of study areas in the Wildlife Refuge Banhado dos Pachecos (BPWR), Viamão municipality, Rio Grande do Sul State, Brazil. **A:** Site 1, showing the landscape mosaic composed of grasslands, swamp forest and dune vegetation. The Banhado Grande dam is shown in the background. **B:** Site 2, showing landscape mosaic composed of grasslands and restiga and slope forests. Small farm properties with eucaliptus monocultures outsite the BPWR are shown in the background.

Pollard 1977) and observation by scanning (modified from Altmann 1974).

Monthly expeditions were performed between April 2012 and March 2013. For the entomological netting method, two sites with mixed formations of Restinga forests, swampy forests, and grasslands were selected as sampling areas to cover habitat heterogeneity. In each site, two collectors covered two transects with entomological nets, totaling a sampling effort of 12 net-hours per month. All net samplings were performed from 9 AM to 4 PM The observations by scanning were performed in two Restinga forest areas, at the end of each site, and had different levels of structural regeneration to cover habitats with distinct conservation levels. Each area was sampled using two replicas of 150 m^2, 100 m distant from each other. The first observation area was in an early stage of regeneration, while the second was in an intermediate stage of regeneration (*sensu* CONAMA 1999). The scanning samplings were always performed between 10 AM and 1 PM (solar time), since this is considered the optimal period for Lepidoptera observation in Restinga environments (Marchiori and Romanowski 2006a). The total sampling effort for observation by scanning was 12 hours of scanning in each area per month. The general sampling effort accounting net and scanning methods was 24 hours per month.

Data analysis

The butterflies collected were primarily identified in the field, with the aid of butterfly guides (Canals 2003; Núñez-Bustos 2010). The specimens with uncertain identification were brought to the laboratory, mounted and identified by consulting reference collections, specialized literature, and specialists. Higher-level classification followed Lamas (2004), Mielke (2005) and Wahlberg et al. (2009), with nomenclature updates when necessary. Whenever possible, two males and two females of each species were collected, mounted, and deposited in the Lepidoptera Collection from the Department of Zoology, Federal University of Rio Grande do Sul, Porto Alegre, Brazil, as voucher specimens (access numbers CLDZ 9,077–9,205 and CLDZ 10,061-10,214).

Data both from transect entomological netting and observation by scanning was pooled and the richness (S), abundance (N), and the number of singleton butterflies scored. First, a list of species organized by family, subfamily and tribe was compiled using all butterfly records during sampling. To investigate new records for the state and for the ecoregion, data obtained from the BPWR were compared to other studies conducted in the Uruguayan Savanna. Then, an analytical examination of these data was performed. Species accumulation curves were calculated, including the observed and estimated total richness with a confidence interval of 95% considering all species pooled and also separately for each family. Analytical richness estimators Jackknife 1, Jackknife 2, ACE, Chao 1 and Chao 2 were calculated to evaluate the richness of butterflies present in the BPWR following Magurran (2004) and Magurran and McGill (2011). All statistics were performed using EstimateS 9.1 (Colwell 2013).

RESULTS

After a total sampling effort of 288 hours, 1,508 individuals from 113 species were recorded in the BPWR. Most of the species (68%) were considered of rare occurrence (*sensu* Magurran 2004) (Table 1). Three specimens of Hesperiidae could not be identified and will need further revision to corroborate their taxonomic status. In addition, five new species records for the Rio Grande do Sul state and 12 for the Uruguayan Savanna ecoregion were recorded. Concerning species representativeness, Nymphalidae had the highest representation, while Riodinidae had the lowest (Table

Table 1. Butterflies recorded in the Banhado dos Pachecos Wildlife Refuge (BPWR), Viamão municipality, Rio Grande do Sul State, Brazil after 288 net-hours of sampling effort. The number of specimens per taxon is shown within parentheses. Specimens with uncertain identification were classified only at the genus level. * New records for Rio Grande do Sul State. # New records for Uruguayan Savanna. Total richness: 113 species.

Family	Subfamily	Tribe	Species	Abundance
Hesperiidae (34)	Eudaminae (7)	Eudamini (7)	*Autochton intergrifascia* (Mabille, 1891)	2
			Autochton neis (Geyer, 1832) #	1
			Autochton zarex (Hübner, 1818)	1
			Urbanus esta Evans, 1952	1
			Urbanus procne (Plötz, 1880)	2
			Urbanus simplicius (Stoll, 1790)	8
			Urbanus teleus (Hübner, 1821)	9
	Hesperiinae (14)	Anthoptini (2)	*Corticea* sp. 1	1
			Corticea sp. 2	1
		Calpodini (1)	*Panoquina hecebolus* (Scudder, 1872)	3
		Hesperiini (6)	*Anatrytone perfida* (Möschler, 1879)* #	1
			Euphyes sp. 1	1
			Euphyes cherra Evans, 1955	1
			Hylephila phyleus phyleus (Drury, 1773)	2
			Nyctelius nyctelius nyctelius (Latreille, [1824])	2
			Polites vibex catilina (Plötz, 1886)	26
		Moncini (5)	*Callimormus rivera* (Plötz, 1882)	4
			Ginungagapus ranesus (Schaus, 1902)	4
			Miltomiges cinnamomea (Herrich-Schäffer, 1869)	9
			Sodalia dimassa (Hewitson, 1876) * #	1
			Zariaspes mys (Hübner, [1808])	1
	Pyrginae (13)	Pyrgini (13)	*Achlyodes mithridates thraso* (Hübner,[1807])	1
			Chiomara asychis autander (Mabille, 1891)	1
			Cogia abdul Hayward, 1947* #	1
			Cogia hassan evansi E. Bell, 1937	4
			Gorgythion begga begga (Prittwitz, 1868)	2
			Gorgythion beggina escalophoides Evans, 1953	6
			Helias phalaenoides phalaenoides Fabricius, 1807 * #	2
			Heliopetes arsalte (Linnaeus, 1758)	9
			Heliopetes omrina (Butler, 1870)	11
			Oechydrus chersis evelinda (Butler, 1870)	1
			Pyrgus orcus (Stoll, 1780)	72
			Spathilepia clonius (Cramer, 1775)	1
			Xenophanes tryxus (Stoll, 1780)	1
Lycaenidae (14)	Polyommatinae (1)		*Hemiargus hanno hanno* (Stoll, 1790)	3
	Theclinae (13)	Eumaeini (13)	*Arawacus separata* (Lathy, 1926)	8
			Aubergina vanessoides (Prittwitz, 1865) #	1
			Calycopis caulonia (Hewitson, 1877)	4
			Cyanophrys acaste (Prittwitz, 1865)	1
			Cyanophrys herodutus (Fabricius, 1793)	1
			Evenus latreillii (Hewitson, 1865)	1
			Ministrymon cruenta (Gosse, 1880) #	1
			Parrhasius polibetes (Stoll, 1781) #	1
			Rekoa palegon (Cramer, 1780)	2
			Strymon bazochii (Godart, [1824])	2
			Strymon lucena (Hewitson, 1868)	1
			Strymon rana (Schaus, 1902) * #	1
			Tmolus echion echiolus (Draudt, 1920) #	1
Nymphalidae (39)	Apaturinae (1)		*Doxocopa laurentia laurentia* (Godart, [1824])	2
	Biblidinae (2)	Ageroniini (2)	*Hamadryas amphinome amphinome* (Linnaeus, 1767)	1
			Hamadryas februa februa (Hübner, [1823])	3
		Catonephelini (1)	*Eunica eburnea* Fruhstorfer, 1907	133
	Charaxinae (1)	Preponini (1)	*Archaeoprepona amphimachus pseudomeander* (Fruhstorfer, 1906)	2
			Caligo martia (Godart, [1824])	2
	Cyrestinae (1)	Cyrestini (1)	*Marpesia petreus petreus* (Cramer, 1776)	2
	Danainae (3)	Danaini (2)	*Danaus eresimus plexaure* (Godart, 1819)	1
			Danaus gilippus gilippus (Cramer, 1775)	6
		Ithomiini (1)	*Methona themisto* (Hübner, 1818)	1

Continued

Table 1. *Continued.*

Family	Subfamily	Tribe	Species	Abundance
	Heliconiinae (8)	Acraeini (1)	*Actinote carycina* Jordan, 1913	8
		Argynnini (1)	*Euptoieta hortensia* (Blanchard, 1852)	2
			Agraulis vanillae maculosa (Stichel, [1908])	30
			Dione juno juno (Cramer, 1779)	3
			Dryadula phaetusa (Linnaeus, 1758)	7
			Dryas iulia alcionea (Cramer, 1779)	177
			Heliconius erato phyllis (Fabricius, 1775)	43
			Heliconius ethilla narcaea (Godart, 1819)	3
	Limenitidinae (3)	Limenitidini (3)	*Adelpha hyas hyas* (Doyère, [1840])	1
			Adelpha syma (Godart, [1824])	6
			Adelpha thessalia indefecta Fruhstorfer, 1913	1
	Nymphalinae (9)	Junoniini (1)	*Junonia evarete* (Cramer, 1779)	128
		Melitaeini (4)	*Ortilia ithra* (W. F. Kirby, 1900)	37
			Ortilia orthia (Hewitson, 1864)	9
			Tegosa claudina (Eschscholtz, 1821)	208
			Tegosa orobia orobia (Hewitson, 1864)	1
		Nymphalini (3)	*Hypanartia bella* (Fabricius, 1793)	7
			Vanessa braziliensis (Moore, 1883)	47
			Vanessa myrinna (E. Doubleday, 1849)	8
		Victoriini (1)	*Anartia amathea roeselia* (Eschscholtz, 1821)	82
	Satyrinae (10)	Brassolini (2)	Blepolenis batea didymaon (C. Felder & R. Felder, 1867)	10
		Morphini (2)	*Morpho epistrophus catenaria* Perry, 1811	1
			Morpho aega aega (Hübner, [1822])	2
		Satyrini (6)	*Carminda griseldis* (Weymer, 1911) [#]	3
			Hermeuptychia gisella (Hayward, 1957)	5
			Stegosatyrus periphas (Godart, [1824])	8
			Paryphthimoides phronius (Godart, [1824])	5
			Paryphthimoides poltys (Prittwitz, 1865)	3
			Yphthimoides celmis (Godart, [1824])	25
Papilionidae (12)	Papilioninae (12)	Leptocircini (1)	*Mimoides lysithous* (Hübner, [1821])	2
		Papilionini (5)	*Heraclides anchisiades capys* (Hübner, [1809])	2
			Heraclides astyalus astyalus (Godart, 1819)	15
			Heraclides hectorides (Esper, 1794)	4
			Heraclides thoas brasiliensis (Rothschild & Jordan, 1906)	3
			Pterourus scamander scamander (Boisduval, 1836)	1
		Troidini (6)	*Battus polydamas polydamas* (Linnaeus, 1758)	40
			Battus polystictus polysticus (A. Butler, 1874)	4
			Euryades corethrus (Boisduval, 1836)	62
			Parides agavus (Drury, 1782)	3
			Parides bunichus perrhebus (Boisduval, 1836)	2
			Parides proneus (Hübner, [1831])	1
Pieridae (10)	Coliadinae (7)		*Eurema albula sinoe* (Godart, 1819)	4
			Eurema deva deva (E. Doubleday, 1847)	80
			Eurema elathea flavescens (Chavannes, 1850)	14
			Phoebis argante argante (Fabricius, 1775)	3
			Phoebis neocypris neocypris (Hübner, [1823])	2
			Phoebis sennae marcellina (Cramer, 1777)	1
			Rhabdodryas trite banksi (Breyer, 1939)	1
	Pierinae (3)	Anthocharidini (2)	*Hesperocharis paranensis paranensis* Schaus, 1898	1
			Tatochila autodice autodice (Hübner, 1818)	1
		Pierini (1)	*Ascia monuste automate* (Burmeister, 1878)	1
Riodinidae (4)	Euselasiinae (1)	Euselasiini (1)	*Euselasia hygenius occulta* Stichel, 1919	1
	Riodininae (3)	Eurybiini (1)	*Chalodeta theodora* (C. Felder & R. Felder, 1862)	2
		Riodinini (1)	*Calephelis braziliensis* McAlpine, 1971	14
		Symmachiini (1)	*Stichelia bochoris suavis* (Stichel, 1911) [#]	1

Table 2. Comparison of butterfly richness (S) and compositions between localities situated in the Uruguayan Savanna Ecoregion. The relative percentages are shown in parentheses

Localities	Nymphalidae	Hesperiidae	Lycaenidae	Riodinidae	Pieridae	Papilionidae	Total S	Sampling effort	S / net-hour
Viamão (BPWR. RS, Brazil)[1]	40 (16.7)	34 (14.2)	14 (5.8)	4 (1.7)	10 (4.2)	13(5.4)	113	288	0.39
Barra do Quaraí (Espinilho State Park, RS, Brazil)[2]	36 (37)	25 (26)	9 (9)	9 (9)	14 (15)	4 (4)	97	300	0.32
Santa Maria (Campus UFSM, RS, Brazil)[3]	40 (45)	25 (28)	8 (9)	2 (2.5)	11 (12)	3 (3.5)	89	113	0.79
Uruguaiana (Municipal Park, RS, Brazil)[4]	23 (50)	11 (24)	2 (4.5)	2 (4.5)	7 (15)	1 (2)	46	99	0.46
Isla Martin Garcia (Argentina)[5]	48 (37)	42 (32)	15 (11)	7 (5)	13 (10)	7 (5)	132	279	0.47
Canguçu/Caçapava do Sul (RS, Brazil)[6,A]	59 (72.8)	N/A	N/A	N/A	10 (12.3)	12 (14.8)	81	289	0.28
Rio Grande (RS, Brazil)[7,]	27 (27.5)	39 (39.5)	10 (10.5)	6 (6)	12 (12.5)	4 (4)	98	216	0.45
Pelotas (RS, Brazil)[8]	107(51.4)	N/A	36 (17.3)	29 (13.9)	26 (12.5)	10 (4.8)	84	208	0.40
Uruguay [9,B]	107 (36)	97 (32.6)	23 (7.7)	30 (10)	27 (9.1)	13 (4.3)	297	N/A	N/A

References: 1, present study; 2, Marchiori and Romanowski 2006b; 3, Sackis and Morais 2008; 4, Rosa et al. 2011; 5, Núñez-Bustos 2007; 6, Paz et al. 2008; 7, Carvalho and Morais 2015; 8, Krüger and Silva 2003; 9, Bentancur-Viglione 2009. A. Data from Hesperiidae, Lycaenidae, and Riodinidae not included in the original paper. B. Data from Hesperioidea not included in the original paper. C. Compilation list from several references and records from entomological collections with no sampling effort available.

2). The randomized species accumulation curve did not reach stabilization considering all families pooled (Figure 3a); although the curves for Pieridae, Papilionidae, and Riodinidae families seem to be very close to stabilization (Figure 3b). Such results suggest that the richness of butterflies in the BPWR was not fully registered with the sampling effort used. According to the analytical estimators of richness, the total number of butterfly species present in the BPWR may vary between 165 and 201 (mean = 179). Thus, the observed number of species represents approximately 64% of species present in the BPWR, which is considered excellent concerning short-term inventories (Magurran 2004).

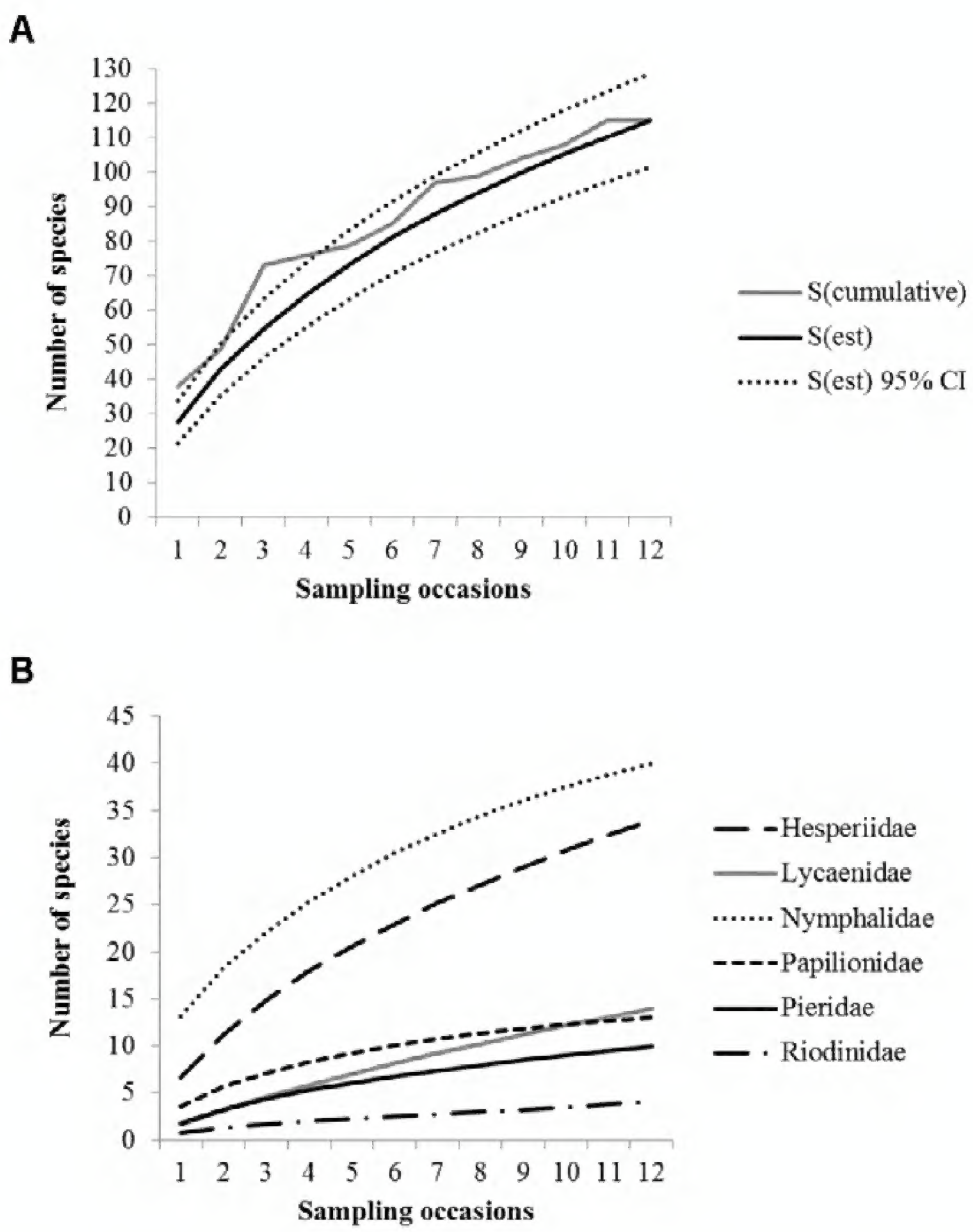

Figure 3. Number of species recorded after 12 sampling occasions in the Wildlife Refuge Banhado dos Pachecos, Viamão municipality, Rio Grande do Sul State, Brazil. **A:** Cumulative observed (S) and estimated (Sest) plus confidence interval number of species considering all families pooled. **B:** Cumulative estimated number of species per family.

DISCUSSION

Despite the efforts applied to uncover the butterfly species present in the BPWR, we expect more species to be found with the increasing of sampling efforts, especially for the families Hesperiidae and Nymphalidae. The number of Hesperiidae species recorded was lower than the number of Nymphalidae species, contrasting to other studies throughout the Neotropics (Brown Jr. and Freitas 1999, 2000; Núñez-Bustos 2008; Núñez-Bustos et al. 2011; Núñez-Bustos and Volkmann 2013; Lima and Zacca 2014; Carvalho and

Morais 2015). The probable cause for the low number of Hesperiidae species in the BPWR is the high number of rare species found. It is known that the Hesperiidae species accumulation curves need more sampling events to reach the same stabilization level as observed for Nymphalidae (Iserhard et al. 2013). It was also expected that Lycaenidae and Riodinidae species curves did not reach stabilization, because the populations of those butterflies show patched distribution, generally are syntopic with the occurrence of their host-plants (New 1993), have seasonal occurrence, and are very sensitive to environmental fluctuation (Iserhard et al. 2013). Short and mid-term inventories are expected to produce incomplete species lists, and due to the nature of population density of rare species, only continuous inventories can reach the asymptote of the theoretical curve of species accumulation. Thus, it is recommended to keep monitoring the butterfly community in the BPWR in order to increase the recording of species.

Notwithstanding the fact that the accumulation curves still exhibit a general trend of increasing the number of species in the BPWR, the present study raised the number of butterfly species recorded in Rio Grande do Sul state from 832 to 838, and in the Uruguayan Savanna from 596 to 609. In relative frequencies, the number of butterfly species found in the BPWR represents nearly 13% of the total of species recorded for the Rio Grande do Sul state (Giovenardi et al. 2013) and 19% of the total of species recorded for the Uruguayan Savanna (compiled from Biezanko et al., 1978; Bentancur-Viglione 2009; Giovenardi et al. 2013). When compared to other butterfly inventories conducted in the Uruguayan Savanna areas, BPWR exhibited the second lowest rate of species registered per net-hour, only ahead Barra do Quaraí and Canguçu/Caçapava do Sul (Table 2). The greatest rate was observed in Santa Maria, an ecological tension area between Pampa and Atlantic Forest biomes. Hence, the elevated rate of species per net-hour may result from the proximity of the two biomes, caused by the overlap of the fauna from both biomes.

Considering the increase of landscape fragmentation in the past few decades in the Uruguayan Savanna, it is evident that not only has the advance of the metropolitan region towards the Pampa been severely affecting the biodiversity loss, but intense agricultural practices and overgrazing activities have also been producing similar effects (Roesch et al. 2009). Agriculture brings a number of profound changes that affect virtually all aspects of ecological processes, from the behavior of individuals and population dynamics to the composition and structure of communities (Gilpin et al. 1992). Agriculture directly affects the entire food chain by altering the flows of matter and energy through ecosystems, and the evidence accumulated so far strongly suggest that the implementation of agro-ecosystems is undoubtedly the main force causing environmental changes (Bilenca et al. 2009).

Regarding the conservation of Lepidoptera, the main threat to endangered species of Brazil is the loss of their natural habitats (Casagrande and Mielke 1995; Brown Jr. 1996; Casagrande et al. 1998; Freitas and Marini-Filho 2011). Despite the accumulation of evidence of original habitat losses in the Pampa biome (Santos and Silva 2012), very little has been done to estimate and preserve present day butterfly diversity in the Uruguayan Savanna. The results presented here contribute to increase the knowledge of the Neotropical butterfly fauna, and also reinforce the importance of biodiversity studies for areas that urgently need management programs. Inventories of fauna, particularly those of butterflies, have great potential to produce useful information for management and conservation programs. In addition, diversity of lepidopteran communities in preserved areas is the baseline to support the restoration monitoring of fragmented areas. It is remarkable how a small preservation area in a nearly metropolitan region can hold such rich fauna. Such results may serve as a warning and a stimulus towards the establishment of small protected areas, since larger ones are nearly impossible to create near big cities.

ACKNOWLEDGMENTS

The authors thank Carolina Prauchner, Cristiane da Silva, Guilherme Atencio, Lidiane Fucilini, Luiza Moucachen, and Nicole Rappa for helping with butterfly sampling. Special thanks are due to Alfred Moser, André Freitas, Cristiano Iserhard, Eduardo Carneiro, Diego Dolibaina, and Ricardo Siewert for assistance with some butterfly identification, and to SEMA-RS, for the collection license #01/2012. ACC received grants from PIBIC/UFRGS/CNPq, LBM PPGBAN/CAPES, NOM PNPD/CAPES (#23038.8306/2010-62) and HPR CNPq (#307635/2010-4) and SiSBiota/RedeLep (#563332/2010-7). This is contribution #575 from the Department of Zoology at the Federal University of Rio Grande do Sul.

LITERATURE CITED

Accordi, I.A. and A. Barcellos. 2006. Composição da avifauna de oito áreas úmidas da Bacia Hidrográfica do Lago Guaíba, Rio Grande do Sul. Revista Brasileira de Ornitologia 14(2): 101–115.

Altmann, J. 1974. Observational study of behavior — sampling methods. Behavior 49(3/4): 227–267. doi: 10.1163/156853974X00534

Bentancur-Viglione, M.G. 2009. Lista de los Papilionoidea y Hesperioidea del Uruguay (Insecta: Lepidoptera). SHILAP Revista de Lepidopterología 37(145): 23–40

Biezanko, C.M., O.H.H. Mielke, and A. Wedderhoof. 1978. Contribuição ao estudo faunístico dos Riodinidae do Rio Grande do Sul, Brasil (Lepidoptera). Acta Biológica Paranaense 7(1): 7–22.

Bilenca, D.N. and F.O Miñarro. 2004. Identificación de Áreas Valiosas de Pastizal (AVPs) en las Pampas y Campos de Argentina, Uruguay y sur de Brasil. Buenos Aires: Fundación Vida Silvestre. 323 pp.

Bilenca, D.N., M. Codesido and C.G. Fischer. 2009. Uso de la tierra y biodiversidad en agroecosistemas de la provincia de Buenos

Aires: cambios hacia el interior de la frontera agropecuária; pp. 345–355, in: V.P. Pillar, S.C. Müller, Z.M.S. Castilhos and A.V.A. Jacques (eds.). Campos Sulinos — conservação e uso sustentável da biodiversidade. Brasília: Ministério do Meio Ambiente.

Boldrini. I.I. 2009. A flora dos Campos do Rio Grande do Sul; pp. 63–77, in: V.P. Pillar, S.C. Müller, Z.M.S. Castilhos and A.V.A. Jacques (ed.). Campos Sulinos — conservação e uso sustentável da biodiversidade. Brasília: Ministério do Meio Ambiente.

Boldrini, I.I., P.M.A. Ferreira, , B.O. Andrade, A.A. Schneider, R.B. Setubal, R. Trevisan and E.M. Freitas. 2010. Bioma Pampa: diversidade florística e fisionômica. Porto Alegre: Pallotti. 61 pp.

Bonebrake, T.C., J. Christensen, C.L. Boggs and P.R. Ehrlich. 2010. Population decline assessment, historical baselines, and conservation. Conservation Letters 3(6): 371–378. doi: 10.1111/j.1755-263X.2010.00139.x

Brown Jr, K.S. 1996. Conservation of threatened species of Brazilian butterflies; pp. 45–62, in: S.A. Ae, T. Hirowatari, M. Ishii and L.P. Brower (eds.). Decline and conservation of butterflies in Japan, Vol 3. Osaka: Lepidopterists Society of Japan.

Brown Jr, K.S. 1997. Diversity, disturbance, and sustainable use of Neotropical forests — insects as indicators for conservation monitoring. Journal of Insect Conservation 1(1): 25–42. doi: 10.1023/A:1018422807610

Brown Jr, K.S. and A.V.L. Freitas. 1999. Lepidoptera; pp. 225–245, in: C.R.F. Brandão and E.M. Cancello (eds.). Biodiversidade do Estado de São Paulo, Brasil. São Paulo: FAPESP.

Brown Jr, K.S. and A.V.L. Freitas. 2000. Atlantic Forest butterflies: indicators for landscape conservation. Biotropica 32 (4b): 934–956. doi: 10.1111/j.1744-7429.2000.tb00631.x

Bunde, P.R.S., J. Grazia, M.S. Mendonça Jr, C.F. Schwertner, E.J.E. Silvaand E.M. Garcia, E.M. 2010. Pentatomidade (Hemiptera, Heteroptera) of the Pampa biome — Serra do Sudeste and Parque de Espinilho da Barra do Quaraí, Rio Grande do Sul, Brazil. Biota Neotropica 10(3): 83–88. doi: 10.1590/S1676-06032010000300008

Carvalho, A.P. and A.B.B. Morais. 2015. Borboletas associadas a ambientes de restinga no extremo sul do Brasil (Lepidoptera, Papilionoidea). SHILAP Revista de Lepidopterología 42(167): 1–15.

Casagrande, M.M. and O.H.H. Mielke. 1995. Borboletas Ameaçadas de Extinção no Estado Paraná; pp. 143–157, in: SEMA/GTZ (ed.). Lista Vermelha de Animais Ameaçados de extinção no Estado do Paraná. Curitiba: SEMA/GTZ.

Casagrande, M.M., O.H.H. Mielke and K.S. Brown Jr. 1998. Borboletas (Lepidoptera) ameaçadas de extinção em Minas Gerais, Brasil. Revista Brasileira de Zoologia 15(1): 241–259. doi: 10.1590/S0101-81751998000100021

Cigliano, M.M., M.L.Wysiecki and C.E. Lange. 2000. Grasshopper (Orthoptera Acridoidea) species diversity in the Pampas, Argentina. Diversity and Distributions 6(2): 81–91. doi: 10.1046/j.1472-4642.2000.00077.x

Colwell, R.K. 2013. Estimates 9.1: statistical estimation of species richness and shared species from samples. University of Connecticut, Connecticut. Accessed at http://viceroy.eeb.uconn.edu/estimates, 29 July 2015.

CONAMA. 1999. Biomas — Estágios sucessionais da vegetação de restinga. Resolução CONAMA 261. Brasília: Ministério do Meio Ambiente. 10 pp.

CSR/IBAMA. 2011. Monitoramento do bioma Pampa 2008–2009. Brasília: CID Ambiental. 29 pp.

Da Silva, P.G., F.Z. Vaz-de-Mello and R.A. Di Mare. 2013. Diversity and seasonality of Scarabaeinae (Coleoptera: Scarabaeidae) in forest fragments in Santa Maria, Rio Grande do Sul, Brazil. Anais da Academia Brasileira de Ciências 85(2): 679–697. doi: 10.1590/S0001-37652013005000033

Eva, H.D., E.E. Miranda, C.M. Di Bella, V. Gond, O. Huber, M. Sgrenzaroli, S. Jones, A. Coutinho, A. Dorado, M. Guimarães, C. Elvidge, F. Achard, A.S. Belward, E. Bartholom, A. Baraldi, G. De Grandi, P. Vogt, S. Fritz and A. Hartley. 2003. The Land Cover Map for South America in the Year 2000. GLC2000 database, European Commision Joint Research Centre. Accessed at http://www-gem.jrc.it/glc2000, 29 July 2015.

Fahrig, L. 2003. Effects of Habitat Fragmentation on Biodiversity. Annual Review of Ecology, Evolution and Systematics 34: 487–515. doi: 10.1146/annurev.ecolsys.34.011802.132419

Fleishman, E. and D.D. Murphy. 2009. Realistic assessment of the indicator potential of butterflies and other charismatic taxonomic groups. Conservation Biology 23(5): 1109–1116. doi: 10.1111/j.1523-1739.2009.01246.x

Freitas, A.V.L. and O.J. Marini-Filho. 2011. Plano de ação nacional para a conservação dos lepidópteros - Série Espécies Ameaçadas, vol. 13. Brasília: Instituto Chico Mendes de Conservação da Biodiversidade. 122 pp.

Gilpin, M., G.A.E. Gall and D.S. Woodruff. 1992. Ecological dynamics and agricultural landscapes; pp. 27–52, in: G.A.E Staton and M. Gall (eds.). Integrating conservation biology and agricultural production. Special Issue of Agriculture, Ecosystems and Environment, 42. London: Elsevier Applied Science.

Giovenardi, R., R.A. Di Mare, O.H.H. Mielke, M.M. Casagrande and E. Carneiro. 2013. Mariposas de Rio Grande do Sul, Brasil (Lepidoptera: Papilionoidea, Hesperioidea). Revista Colombiana de Entomología 39(2): 267–275.

Hochmüller, C.J.C., M. Lopes-Da-Silva, V.L.S. Valente and H.J. Schmitz. 2010. The drosophilid fauna (Diptera, Drosophilidae) of the transition between the Pampa and Atlantic Forest Biomes in the state of Rio Grande do Sul, southern Brazil first records. Papéis Avulsos de Zoologia 50(19): 285–295.

IBGE. 2004. Mapa de Biomas do Brasil. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro. Accessed at http://www.ibge.gov.br/home/geociencias/default_prod.shtm#USO, 29 July 2015.

IBGE. 2007. Censo Agropecuário 2006. Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro. 141 pp.

Iserhard, C.A., K.S. Brown Jr and A.V.L. Freitas. 2013. Maximized sampling of butterflies to detect temporal changes in tropical communities. Journal of Insect Conservation 17(3): 615–622. doi: 10.1007/s10841-013-9546-z

Krüger, C.P. and E.J.E. Silva. 2003. Papilionoidea (Lepidoptera) de Pelotas e seus arredores, Rio Grande do Sul, Brasil. Entomología y Vectores 10(1): 31–45

Lamas, G. 2004. Checklist Part 4A, Hesperioidea – Papilionoide; pp. 1–439, in: J. Heppner (ed.). Atlas of Neotropical Lepidoptera. Gainsville: Scientific Publishers.

Lewinsohn, T.M., A.V.L. Freitas and P.I. Prado. 2005. Conservation of terrestrial invertebrates and their habitats in Brazil. Conservation Biology 19(3): 640–645. doi: 10.1111/j.1523-1739.2005.00682.x

Lima, J.N.R. and T. Zacca. 2014. Lista de Espécies de Borboletas de uma Área de Semiárido na Região Nordeste do Brazil. EntomoBrasilis 7(1): 33–40. doi: 10.12741/ebrasilis.v7i1.351

Littlewood, N.A., A.J.A. Stewart and B.A. Woodcock. 2011. Science into practice — How can fundamental science contribute to better management of grasslands for invertebrates? Insect Conservation and Diversity 5(1): 1–8. doi: 10.1111/j.1752-4598.2011.00174.x

Lomov, B., D.A. Keith, D.R. Britton, and D.F. Hochuli. 2006. Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. Ecological Management & Restoration 7(3): 204–210. doi: 10.1111/j.1442-8903.2006.00310.x

Magurran, A.E. 2004. Measuring biological diversity. Oxford: Wiley-Blackwell. 264 pp.

Magurran, A.E. and B.J. Mcgill. 2011. Biological diversity: frontiers in measurement and assessment. Oxford: University Press. 368 pp.

Marchiori, M.O. and H.P. Romanowski. 2006a. Species composition

and diel variation of a butterfly taxocenose (Lepidoptera: Papilionoidea e Hesperiioidea) in a restinga forest at Itapuã State Park, southern Brazil. Revista Brasileira de Zoologia 23(2): 443–454. doi: 10.1590/S0101-81752006000200019

Marchiori, M.O. and H.P. Romanowski. 2006b. Borboletas (Lepidoptera, Papilionoidea e Hesperioidea) do Parque Estadual do Espinilho e entorno, Rio Grande do Sul, Brasil. Revista Brasileira de Zoologia 23(4): 1029–1037. doi: 10.1590/S0101-81752006000400007

Marchiori, M.O., M.S. Mendonça Jr, and H.P. Romanowski. 2014. Mariposas en dos ambientes forestales contrastantes en el sur de Brasil (Lepidoptera: Papilionoidea). SHILAP Revista de Lepidopterología 41(166): 1–15.

Mendonça Jr, M.S., C.F. Schwertner and J. Grazia. 2009. Diversity of Pentatomoidea (Hemiptera) in riparian forests of southern Brazil — taller forests, more bugs. Revista Brasileira de Entomologia 53(1): 121–127. doi: 10.1590/S0085-56262009000100026

Mendonça Jr, M.S., B. Winck, R. Baldissera, W. Drose, C.F. Dias, M.Z. David, T.P.S. Toma and L.R. Podgaiski. 2015. Biodiversidade de artrópodos; pp. 61–69, in: V.P. Pillar and O. Lange. (eds.). Os Campos do Sul. Porto Alegre: UFRGS.

Mielke, O.H.H. 2005. Catalogue of the American Hesperioidea: Hesperiidae (Lepidoptera). Curitiba: Sociedade Brasileira de Zoologia. 3344 pp.

MMA. 2007. Priority areas for the conservation, sustainable use and benefit sharing of Brazilian biological diversity. Brasilia: Ministry of the Environment. 348 pp.

Morais, A.B.B, R. Lemesand C.D. Ritter. 2012. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de Val de Serra, região central do Rio Grande do Sul, Brasil. Biota Neotropica 12(2): 175–183. doi: 10.1590/S1676-06032012000200017

Motta, P.C. 2002. Butterflies from the Uberlândia region, Central Brazil: Species list and biological comments. Brazilian Journal of Biology 62(1): 151–163. doi: 10.1590/S1519-69842002000100017

New, T.R. 1993. Conservation biology of Lycaenidae (Butterflies). Occasional Paper of the IUCN Species Survival Commission 8. Gland: IUCN.

Núñez-Bustos, E.O. 2007. Biogeografía de los Rhopalocera de la isla Martín García, provincia de Buenos Aires, Argentina (Lepidoptera: Papilionoidea y Hesperioidea). SHILAP Revista de Lepidopterología 35(139): 289–309.

Núñez-Bustos, E.O. 2008. Diversidad de Mariposas Diurnas en la Reserva Privada Yacutinga, Provincia de Misiones, Argentina (Lepidoptera: Hesperioidea y Papilionoidea). Tropical Lepidoptera Research 18(2): 78–87.

Núñez-Bustos, E.O. 2010. Mariposas de la Ciudad de Buenos Aires y alrededores. Buenos Aires: Vazques-Manzzini. 264 pp.

Núñez-Bustos, E.O., P. Favre, M.P. Bertolini, J.D. Turner and A. Sourakov. 2011. Mariposas diurnas (Lepidoptera: Papilionoidea y Hesperioidea) de la Reserva Privada Osununú-Parque Provincial Teyú Cuaré y Alrededores de San Ignacio, Provincia de Misiones, Argentina. Tropical Lepidoptera Research 21(1): 34–42.

Núñez-Bustos, E.O. and L. Volkmann. 2013. Lepidopterofauna de mariposas diurnas de las Sierras de Guasayán Provincia de Santiago del Estero Argentina. SHILAP Revista de Lepidopterología 41(163): 383–393.

Olson, D.M., E. Dinerstein, E.D. Wikramanayake, N.D. Burgess, G.V.N. Powell, E.C. Underwood, J.A. D'amico, I. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao and K.R. Kassem. 2004. Terrestrial ecoregions of the world: a new map of life on Earth. BioScience 51(11): 933–938. doi: 10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Oostermeijer, J.G.B. and C.A.M. Van Swaay. 1998. The relationship between butterflies and environmental indicator values — a tool for conservation in a changing landscape. Biological Conservation 86(3): 271–280. doi: 10.1016/S0006-3207(98)00040-8

Overbeck, G.E., S.C. Müller, A. Fidelis, J. Pfadenhauera, V.D. Pillar, C.C. Blanco, I.I. Boldrini, R. Both and E.D. Forneck. 2007. Brazil's neglected biome: The South Brazilian Campos. Perspectives in Plant Ecology, Evolution and Systematics 9(2): 101–116. doi: 10.1016/j.ppees.2007.07.005

Paz, A.L.G., H.P. Romanowski, and A.B.B. Morais. 2008. Nymphalidae, Papilionidae e Pieridae (Lepidoptera: Papilionoidea) da Serra do Sudeste do Rio Grande do Sul, Brasil. Biota Neotropica 8(1): 141–149. doi: 10.1590/S1676-06032008000100017

Paz, A.L.G., H.P. Romanowski and A.B.B. Morais. 2013. Borboletas frugívoras do centro oeste do Rio Grande do Sul, Brasil (Lepidoptera: Nymphalidae). SHILAP Revista de Lepidopterología 41(167): 1–14.

Peel, M.C., B.L. Finlayson, and T.A. McMahon, 2007. Updated world map of the Köppen-Geiger climate classification. Hydrology and Earth System Sciences 11(5): 1633–1644. doi: 10.5194/hess-11-1633-2007

Pillar, V.D., S.C. Müller, Z.M.S. Castilhos and A.V.A. Jacques. 2009. Campos Sulinos: conservação e uso sustentável da biodiversidade. Brasília: Ministério do Meio Ambiente. 408 pp.

Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. Biological Conservation 12(2): 115–134. doi: 10.1016/0006-3207(77)90065-9

Roesch, L.F.W., F.C.B. Vieira, V.A. Pereira, A.L. Schünemann, I.F. Teixeira, A.J.T.Senna and V.M. Stefenon. 2009. The Brazilian Pampa — a fragile biome. Diversity 1(2): 182–198. doi: 10.3390/d1020182

Rosa, P.L.P., E.Q. Chiva and C.A. Iserhard. 2011. Borboletas (Lepidoptera: Papilionoidea e Hesperioidea) do Sudoeste do Pampa Brasileiro, Uruguaiana, Rio Grande do Sul, Brasil. Biota Neotropica 11(1): 355–360. doi: 10.1590/S1676-06032011000100032

Rosado, J.L.O., M.G. Gonçalves, W. Dröse, E.J.E. Silva, R.F. Krüger, R.M. Feitosa and A.E. Loeck. 2012. Epigeic ants in vineyards and grassland areas in the Campanha region state of Rio Grande do Sul Brazil. Check List 8(6): 1184–1189.

Sackis, G.D. and A.B.B. Morais. 2008. Borboletas do Campus da Universidade Federal de Santa Maria, RS, Brasil. Biota Neotropica 8(1): 151–158. doi: 10.1590/S1676-06032008000100018

Santos, S. and L.G. Silva. 2012. Mapeamento por imagens de sensoriamento remoto evidencia o bioma pampa brasileiro sob ameaça. Boletim de Geografia 29(2): 49–57. doi: 10.4025/bolgeogr.v29i2.12366

SEMA. 2010. Área de Proteção Ambiental do Banhado Grande. Porto Alegre: Secdo Meio Ambiente. Accessed at http://www.sema.rs.gov.br/conteudo.asp?cod_menu=174, 29 July 2015.

Villwock, J.A. and L.J. Tomazelli. 2007. Planície costeira do Rio Grande do Sul: gênese e paisagem atual; pp. 20–33, in: F.G. Becker, R.A. Ramos and L.A Moura (eds.). Regiões da Lagoa do Casamento e dos Butiazais de Tapes, Planície Costeira do Rio Grande do Sul. Brasília: Ministério do Meio Ambiente.

Wahlberg, N., J. Leneveu, U. Kodandaramaiah, C. Peña, S. Nylin, A.V.L. Freitas and A.V.Z. Brower. 2009. Nymphalid butterflies diversify following near demise at the Cretaceous/Tertiary boundary. Proceedings of the Royal Society B 276(1671): 4295–4302. doi: 10.1098/rspb.2009.1303

Wysiecki, M.L., N.E. Sanchez and S.E. Ricci. 2000. Grassland and shrubland grasshopper community composition in northern La Pampa province, Argentina. Journal of Orthoptera Research 9(1): 211–221. doi: 10.2307/3503649

Author contributions: AC and LBM collected data, mounted the butterflies, and identified the specimens; NOM collected data, identified the specimens, analyzed data and wrote the paper; HPR assembled sample design and helped with paper writing.

Received: 18 August 2015
Accepted: 9 December 2015
Academic editor: Ricardo R. Siewert